An Anode Crisis – The Pitfalls of an Anode Length Increase

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Abstract

The TRIMET Aluminium SE Hamburg smelter changed their anode format in 2017 to reduce the anode current density for future amperage increase. The changes included a new green anode cooling system and a new vibro-compactor to enable production of longer anodes. Further changes in the green anode plant were conducted in the years leading up to the change for the larger anode. The combination of these changes and the raw materials used in the green anode plant had the unfortunate effect that the smelter had an intensive anode crisis resulting in a high green and baked anode scrap ratio in the carbon plant. Furthermore, the anodes produced had a tendency for cracking in the cells. Issues in the electrolysis thermo-chemical system led to high temperature cells. The aluminium output in the electrolysis had to be reduced, as critical cells were cut out of operations and the current was reduced. The findings and the decisions to get back on track are presented in this paper. Additional findings from the literature will put the observations into context with published research.

Keywords: Aluminium electrolysis, Anode crisis, Cracked anodes, Green anode density, Thermo-chemical balance in aluminium electrolysis cells.

1. Introduction

Increasing the capacity of a smelter can be obtained in two ways: expansion or amperage increase. While the first has the potential to increase the capacity in a big step, it has needs in capital investment (between 3300 and 5700 US$ per annual ton [1-3], governmental permits and area available. The second has the potential for plants, especially for ones with area constraints in the surrounding, in amperage creep [4]. Vogelsang et al. showed the potential of smelters increasing from 110 to 175 kA in 1997, a smelter running at 185 kA in 2019 and 68 % above the initial current [5].

While an expansion usually leads to an expansion of the carbon plant as well, the incremental changes for a current creep can lead to a higher carbon need without significant changes on the equipment of carbon plants [6-8].

The TRIMET Aluminum SE smelter in Hamburg is located in the harbor part. As part of a capacity increase project both ways were considered. The plant is limited in its dimensions by the expansion of container terminals and a natural reserve on the other side. An expansion with a further potline was not suitable for the smelter. Therefore, further amperage creep was considered.

Hamburg smelter ran at 180 kA at the time, while smelters with similar cell dimensions like AP18 technologies or a comparable smelter originally designed as an improved design from Hamburg were running at well above 200 kA. The next strategic steps were an increase to 185 and then 190 kA to increase production capacity in the smelter by 5 %.

As a first limitation the anode size was identified, which at the time had an anode current density of 0.86 A/cm^2 at 180 kA. An increase to 190 kA would change that to 0.91 A/cm^2., a value which would not be accepted.

A project for new anode dimensions was started in December 2013. A trial with anodes purchased in China was conducted from January 2015 over a time of 24 months. Finally, in August 2017, the Hamburg smelter changed the anode format– the length increased from 1480 to 1600 – 1625 mm.

The aim was the reduction of energy consumption and a higher current efficiency in the electrolysis due to the larger surface of the anode [8]. It was also deemed a necessary step for further current creep in following years by reducing the anode current density from 0.9 to 0.83 A / cm^2 at the time. Additionally, with a higher baked density, a lower anode height was proposed. This would be beneficial for anode covering and therefore, reduction of air burn. As anodes in the Hamburg smelter are spray coated with aluminium, a saving of ~700 tons aluminium per annum was proposed by elimination of the spray coating, increasing the output of the smelter directly. The target anode height was reduced from 680 to 620 mm, keeping a similar final weight.

2. Planning and Simulation

In order to find proper dimensions for the new anode, measurements were conducted to find the available space in the center channel and the outer channels. It was found, that with the existing retrofit point feeder, a minimal center channel width would be 140 mm (originally 200 mm). This allowed for an increase in length of 30 mm per anode in the center channel. A further reduction would have needed a change for a new feeding system, deemed not financially viable. The main increase of the anode length would have to be towards the side channel, which allowed for an increase of 121 mm until reaching the outer line of the cathode block.

The dimensions of the anodes changed as shown in the following Table 1. The length of 1650 mm can be produced today, however, was never really considered due to its extensive overhang of the cathode.

Table 1. Extension of anodes from original design.

Anode length	Extension side channel	Extension center channel	Out of Cathode shadow
1600 mm	101 mm	19 mm	0 mm
1625 mm	126 mm	19 mm	15 mm
1650 mm	151 mm	19 mm	40 mm

For the reference and new anode dimensions, a thermo-electric model was used to evaluate the heat balance and the ledge formation. The currents used for the evaluation were 180, 182, 185 and 190 kA at the same ACD, which was assumed for the base case. 182 kA is the limitation for the n-1 rectifier operation, with 5 rectifiers running maximum at 47.5 kA.

The models showed that the expected voltage for the larger anodes would be lower than for the base case at 180 kA. None of the models however worked for a current of 180 kA – the anode would touch the calculated ledge. A final model with an increased cover thickness increasing from 6 to 10 cm would allow for operation of the 1600 mm anode at 180 kA.

2.1 Testing Phase

In order to evaluate the maximum dimensions of the anodes, a test with a wooden extension of normal anodes was conducted. This test was conducted in electrolysis cells (see Figure 1 Right) and the rodding shop. It was found that the eventual anode size could not be used during electrical preheating, as the anode would be sitting in or on the ramming paste on the side. Special startup anodes would be required for the future. This enabled a bigger asymmetry and an increase in

5.4 Anode Asymmetry and Yoke Design

With the spatial limitations of the anode enlargement, the asymmetry of the stubs in the anode was increased further. As many cracks occurred in the middle of the anode, which was in between two stub holes (see Figure 1 Left), the yoke located to the outer side of the cell was drawing more current. With the help of KAN-NAK, who simulated the anode and yoke assembly, the following current distributions were found.

Table 2. Relative current distribution (%) in stubs both measured and calculated.

Anode length	Side Channel Stub	Middle Stub	Center Channel Stub
1485 [Simulation]	35	32	33
1625 [Simulation]	36	32	32
1625 [Measured]	35	37	28

Observations showed that cast iron would start to melt in some of the stub holes if the anode was cracked. This led to the assumption that the outer stub would draw as much as 50 % of the anode current in case of a crack.

A comparison of the anode pressure caused by heat up and expansion of the yoke showed that the Hamburg yoke was creating 5 times more pressure in the anode than the yoke design used at Essen. This led to tests with shallow stub holes in the hope this would reduce the pressure of cracking. However, the results were inconclusive.

6. Conclusion

Two dates have had an impact on me as a young process engineer. On 13 December 2017, we had 5 green anodes left, that could be used in the baking furnace. Everything else was scrap. On 12 June 2018, we had 15 cells with bath temperature above 1000 °C. The decision was taken to shut down 10 cells that day in order to save the remaining ones.

These experiences showed, that the changes related to anode dimensions can have severe effects down the process chain. It also shows the need for good process monitoring and process engineering. Since the end of 2018, a process engineer has been included in the carbon plant management to monitor the different parameters. Previously, there was no dedicated process engineer working in the carbon plant. Today, with the increased level of process monitoring, we are better prepared to respond to changes in raw material quality.

The issues in the processes in both carbon and electrolysis showed the power of an interorganizational exchange. With the help of colleagues from the plants in Voerde, Essen and Saint-Jean-de-Maurienne, several changes were implemented for the good.

7. Bibliography

1. Rio Tinto invests to increase low-carbon AP60 aluminium production in Canada, Nov. 17, 2021, https://www.riotinto.com/news/releases/2021/Rio-Tinto-invests-to-increase-low-carbon-AP60-aluminium-production-in-Canada .
2. Joy Liu, Egypt's Metalco to build new aluminum smelter, Apr. 18, 2023. https://yieh.com/en/NewsItem/140599

3. Halvor Molland, Karmoy Technology Pilot, 2021, https://www.hydro.com/Document/Doc/Facts%20Karm%C3%B8y%20technology%20pilot.pdf?docId=5845.
4. Isa Al-Ansari et al., Production growth and future challenges in Aluminium Bahrain (Alba), *Light Metals* 2013, 653-658.
5. D. Vogelsang, I. Eick, M. Segatz, and C. Droste, From 110 to 175 kA: Retrofit of VAW Rheinwerk Part I: Modernization concept, *Essential Readings in Light Metals*, Springer, 2016, 479-484, originally published in *Light Metals* 1997, 233-238.
6. Jean-Claude Fischer *et al.*, Anode issues during smelter capacity creep, *19th International Conference on Nonferrous Metals,* Bhubaneswar, Odisha, India, 2015, 10-11.
7. Barry Sadler, Critical issues in anode production and quality to avoid anode performance problems, Journal of Siberian Federal University. Engineering & Technologies 8(5), 2015: 546-568.
8. Barry J. Welch, The need to respect the interlink between science, physics, and cell design in an environmentally responsible manner: the next big challenge for aluminium smelting, *Light Metals* 2023, 16-23.
9. Christophe Bouché, Bertrand Somnard, and Pasquale Calo, Opportunities and challenges associated to green anode plant upgrade for smelter amperage creeping, in *Light Metals* 2018, 1425-1432.
10. Frischer Wind für die Anoden-Produktion, 2017, https://www.vollert.de/fileadmin/Vollert-Dateiliste/3_Referenzen/3_Aluminium-_und_Stahlindustrie/2017/Trimet/Referenz_Trimet_2017_de.pdf
11. M. Meier, *A view inside anode update 1*, Internal Report RDC-10306, 2017.
12. M. Meier, *Properties of cracked and un-cracked anode butts*, Internal report RDC 10316, 2018.
13. Matthias Dechent, Carbon dust metrics for cell and plant process audits, *Proceedings of 39th International ICSOBA Conference, Virtual Conference,* 22-24 November 2021, Paper AL10, *TRAVAUX* 50, 727-732.